Conceptual Model: Organic Matter in Suisun Marsh
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Estuarine marshes can be the source of substantial amounts of organic matter (OM) in estuaries and coastal oceans (Raymond and Bauer 2001). OM plays an essential role in sustaining food webs, mediating contaminant dynamics, and determining drinking water quality. Our overall conceptual model is that OM has four dominant sources in Suisun Marsh: (1) wetland vegetation and soils, (2) benthic and epibenthic algae, (3) phytoplankton, and (4) allochthonous suspended sediment. Each of these sources has a distinct geographic locus of production, is distinguishable by intrinsic chemical and physical properties, interacts differently with hydrodynamics, and has differential biogeochemical functions and fates in Suisun Marsh. We hypothesize that physical and biological processes act to retain autochthonous and allochthonous particulate organic matter (POM) within the Marsh, while exporting substantial amounts of dissolved organic matter (DOM) to the San Francisco Estuary. Unfortunately not much OM data is available for Suisun Marsh at this time and studies are needed to test this and other hypotheses and to further investigate many aspects of the conceptual model described here.

Sources of OM to Suisun Marsh. The dominant source of OM to Suisun Marsh is likely the tidal and super tidal emergent vegetation that exists within the more geomorphologically intact regions of Suisun Marsh. Phytoplankton and attached algae may also contribute a significant amount of OM, and large algal blooms have been observed in Suisun Marsh (Schroeter et al unpublished, Enright et al, unpublished). Finally, suspended sedimentary material tidally transported from adjacent Grizzly Bay will transfer OM into the Marsh.

Geographic framework. The four OM sources are distributed across the marsh landscape primarily according to bathymetric limitations on growth. Shallow areas and areas inundated by spring tides will primarily support vascular plant production, and are underlain by organic-rich soils. Emergent vegetation may exude DOM directly, or liberate detrital material in to the water during degradation. Shallow quiescent areas will support benthic and epibenthic algal production, while deeper, relatively quiescent channels will support phytoplankton production. In more turbid channels, light attenuation by suspended sediment may limit phytoplankton productivity, as has been shown to occur in San Francisco Bay and the Delta (Cole and Cloern 1987, Jassby et al 2002). Since the primary sediment source to the marsh is the shallow Grizzly Bay, most allochthonous suspended sediment in the marsh will likely originate there.

Hydrologic and meteorologic constraints. Hydrodynamic and meterologic forces will have varying effects on the different OM sources, governed largely by the hydrological connectivity of the geographic sources to the channel network and the Bay. For example, areas with higher elevations, and slough-marsh plain hydrological connectivity during spring tides, are the source of vascular plant-derived DOM and detrital material in Suisun Marsh. Return flows through organic rich surface soils may result in high exports of DOM from marsh plains. An example of a meteorological effect is the potential suppression of phytoplankton production by wind-wave resuspended sediments tidally advected into Suisun Marsh from Grizzly Bay (Schoellhamer et al. 2003).

The impact of a particular OM source on Marsh OM processes and export is likely a function of the hydrodynamic connectivity with the channel network and Bay. For example, sources within one tide length of the Marsh mouth will have a greater impact on export, and those within a tide length of a major channel will be capable of transporting significant material to the channel. Also, hydrodynamic connectivity and channel network development affects residence time (Figure 1a). Longer residence times will permit greater opportunities for planktonic production, photo and microbial degradation of DOM, settling of particulate organic matter, etc. In contrast, in sloughs with shorter residence times, less connectivity with marsh plains and more connectivity with the Bay and Delta, we expect lower biological activity, lower sedimentation rates, and greater transport of DOM and POM (Figure 1b, c). Intermediate residence time regions might be large sinks for fine sediment particles imported from the Bay (Figure 1a), potentially trapping sorbed DOM and contributing to organic matter rich sediments in these regions.

Effects on biology and chemistry. The distribution of OM sources according to the marsh geography and hydrology imposes constraints on the distribution of secondary production within Marsh waters. Vascular plant exudates, soil leachates, and particulate and colloidal plant detritus may represent the most important carbon source for microbial production (Kirschner and Velimirov 1999) and fuel ecosystem metabolism in Suisun Marsh. However, organic matter originating from algae is thought to be of greater bioavailability than vascular plant derived organic matter (Sobczak et al 2002, in press) and may stimulate microbial activity (Preen and Kirchmann 2004). Zones of high algal productivity associated with intermediate residence times may thus have the highest trophic transfer efficiencies from the base of the aquatic food web via invertebrate consumers to fish as well as the highest rates of biological organic matter utilization and transformation (Figure 1b).

We expect the chemical characteristics and interactions of OM within Suisun Marsh to be controlled by the geographic distribution of sources and mechanisms of hydrodynamic transport (Figure 1c) as they are tightly coupled to the zones of production and degradation. Plant-derived organic matter may be relatively rich in hydrophobic humic substances, with high concentrations of phenolics and other aromatic constituents, while phytoplankton derived organic matter may contain less humic substances. DOM exported from wetlands is also rich in colloids, which may be grazed directly or aggregate into larger sinking particles. These chemical characteristics influence OM bioavailability and may also impact the production, transport and uptake of Hg into the foodweb. Up to 50% of the MMHg in the San Francisco Estuary has been found associated with DOM, and half of that associated with colloids (Choe and Gill, 2003). Mercury binding and sediment partitioning have been related to the aromatic content of DOM which is also elevated in wetland-derived material. The distribution of Hg species appear to be a function of the source and composition of the dissolved organic material (Babiarz et al., 2003), which determines the concentration of strong binding sites within the organic material (Ravichandran, et al., 1999; Waples, et al., 2001).

OM Exports. The large amounts of organic matter produced in tidal marshes can lead to substantial organic matter exports to estuarine and coastal waters as has been found for the San Francisco Estuary (Jassby et al 1993, Stepanauskas et al., 2003) and elsewhere (e.g. Raymond and Bauer 2001). Based on these findings, we expect that a substantial portion of Suisun Marsh-produced DOM may be exported to the Bay. In contrast to DOM, POM produced in or imported into the Marsh may be largely retained in the Marsh because Suisun Marsh may act as a sink for particles and POM consumption rates may be high. A recent study found higher particulate organic carbon (POC) levels in the northern, interior part of the Marsh than in the southern part of the Marsh near Suisun Bay and the Delta (Enright et al., unpublished), supporting trapping of POM.

Effects of anthropogenic changes. Anthropogenic changes to marsh geomorphology and hydrology may substantially alter the patterns and processes described above and lead to changes in quantity and quality of organic matter within and exported from the Marsh and related biogeochemical processes. For example, a decrease in channel network complexity may be associated with increased connectivity with the Bay, decreased marsh plain connectivity, and fewer high and medium residence time areas which may result in lower plant and algae production and lower water and sediment organic matter concentrations. Conversely, decreased particle settling and burial due to lower residence times along with increased proportions of recalcitrant peat soil leachates relative to more bioavailable, fresh plant and algal organic matter may decrease organic matter bioavailability and increase the relative amounts of more recalcitrant DOM characterized by higher amounts of humic substances in exported DOM. Also, altered timing and frequency of hydrological connectivity between marsh plains and sloughs (e.g., as the result of wetland management by duck clubs) probably causes substantial changes in organic matter dynamics and associated biogeochemical processes in these wetlands and adjacent sloughs. For example, low dissolved oxygen conditions have been observed in several Suisun Marsh sloughs after release of managed wetland water into these sloughs. The conditions indicate unusually high community respiration and possibly nitrification rates resulting from a short-term increase in organic matter and nutrients.

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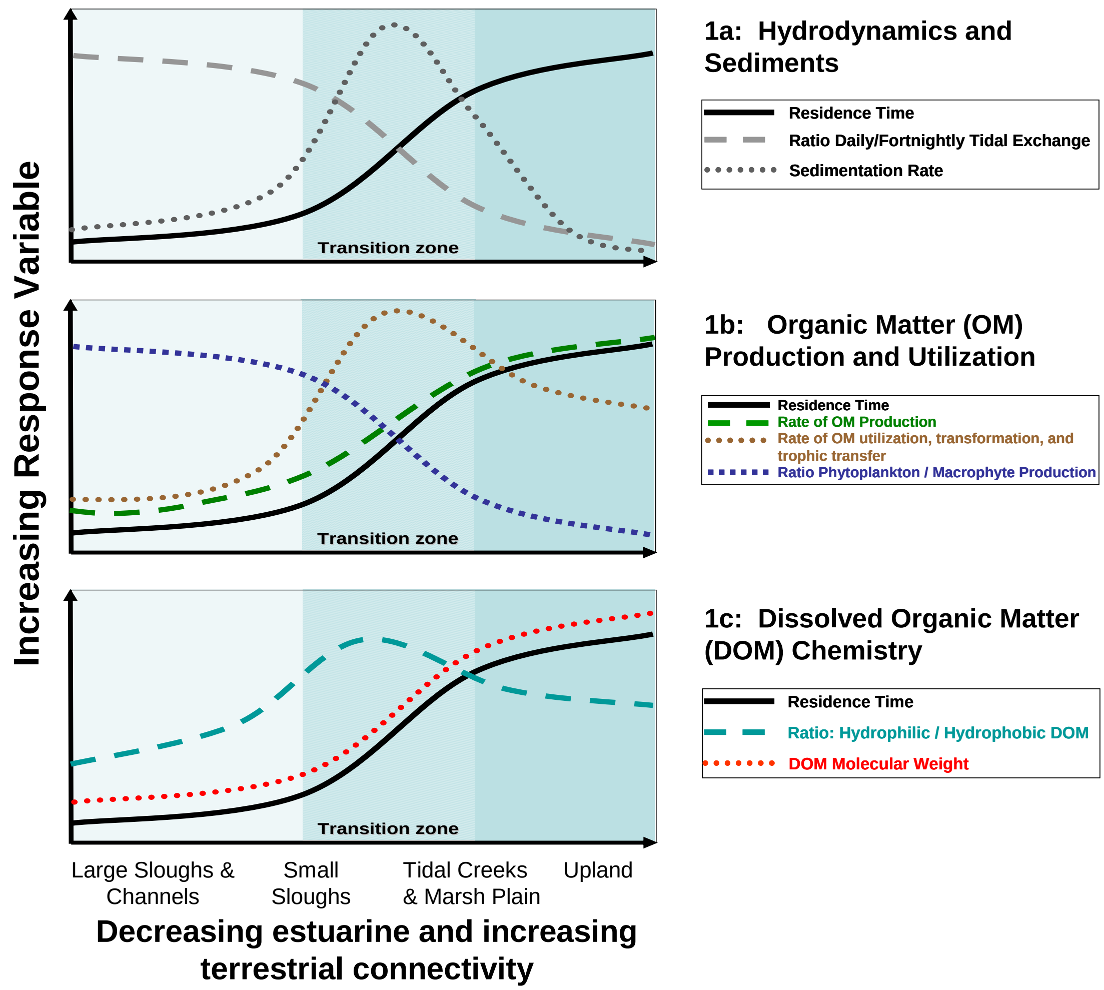

Figure 1: Conceptual Model showing interrelationships among physical, chemical, and biological variables related to organic matter production, utilization, and chemistry along a hydrological connectivity gradient from San Francisco Estuary to Suisun Marsh uplands.